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(54) **APPARATUS AND METHOD TO EFFICIENTLY COOL A COMPUTING DEVICE**

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H01L 23/473 (2006.01)
G06F 1/20 (2006.01)

(52) **U.S. Cl.**

CPC ***G06F 1/203*** (2013.01); ***H05K 7/20145*** (2013.01); ***H01L 23/473*** (2013.01); ***H01L 23/4735*** (2013.01)

(58) **Field of Classification Search**

USPC 361/690
See application file for complete search history.

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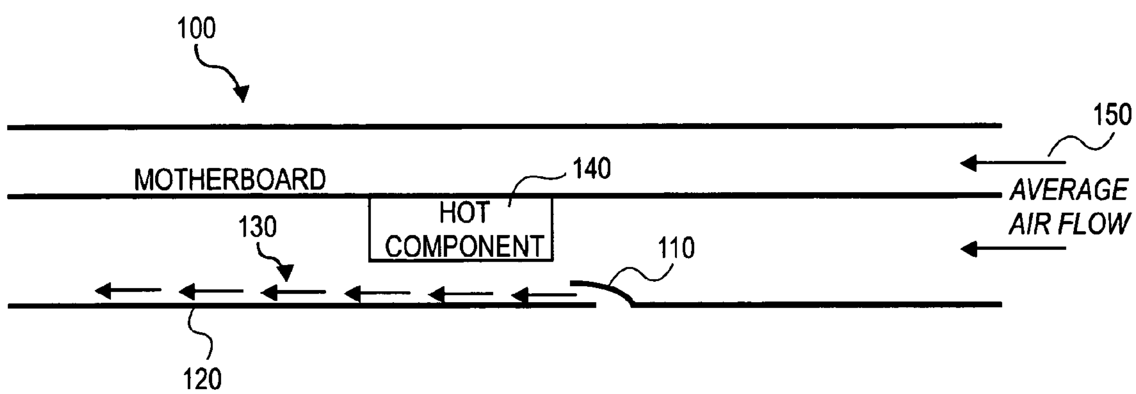
(57) **ABSTRACT**

Embodiments disclosed herein include devices to cool the walls of a mobile computing device. In one embodiment, a louvered vent is formed within an external wall of a mobile computing device to create an air curtain between the external wall and a heat generating component to cool the external wall. In another embodiment, a nozzle vent is formed within the external wall of a mobile computing device to flow cooling air at a heat generating component to cool the heat generating component.

13 Claims, 6 Drawing Sheets



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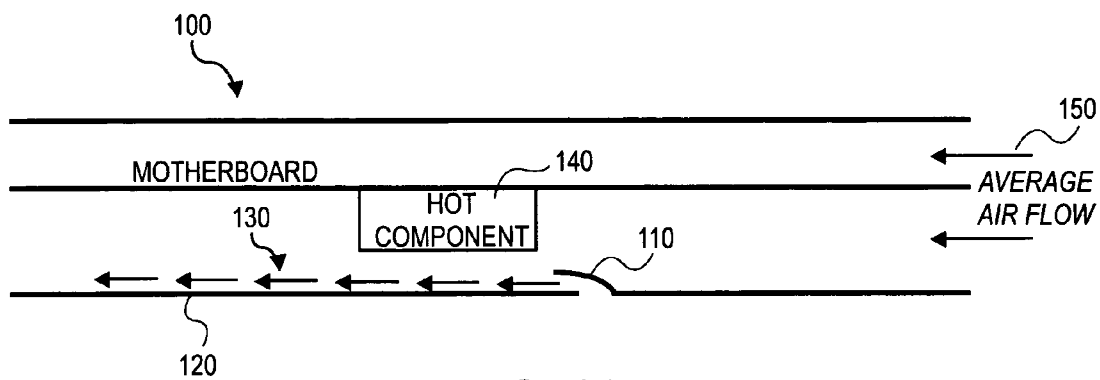


FIG. 1A

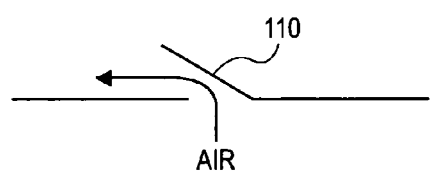


FIG. 1B

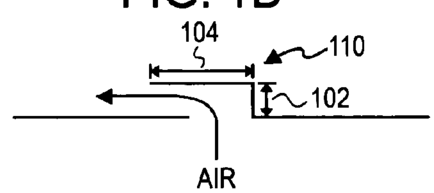


FIG. 1C

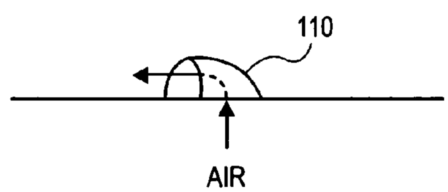


FIG. 1D

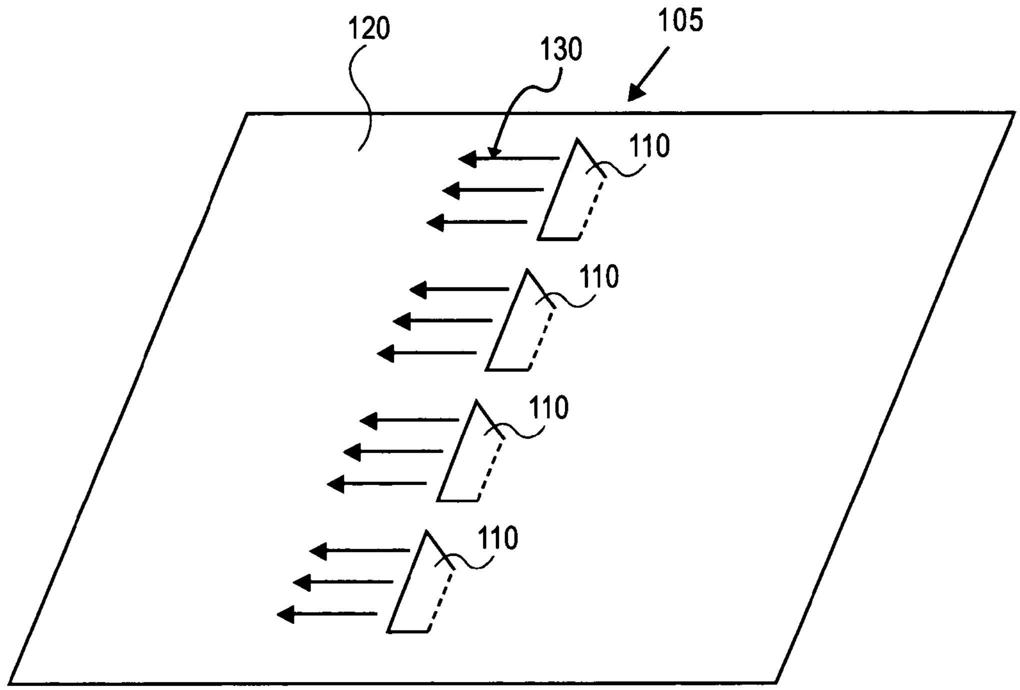


FIG. 2A

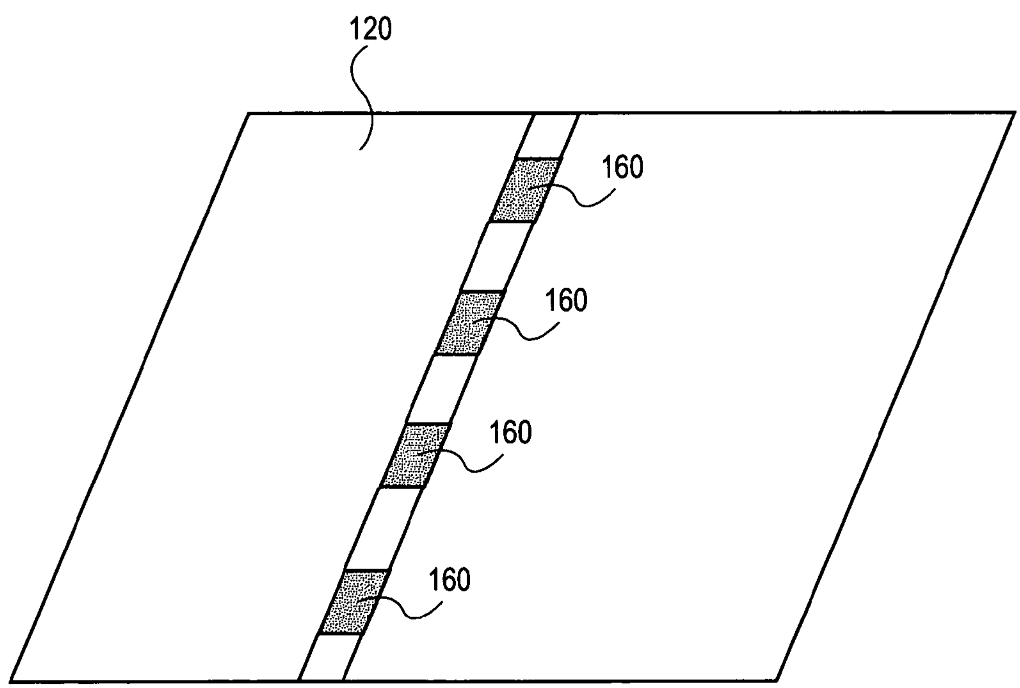


FIG. 2B

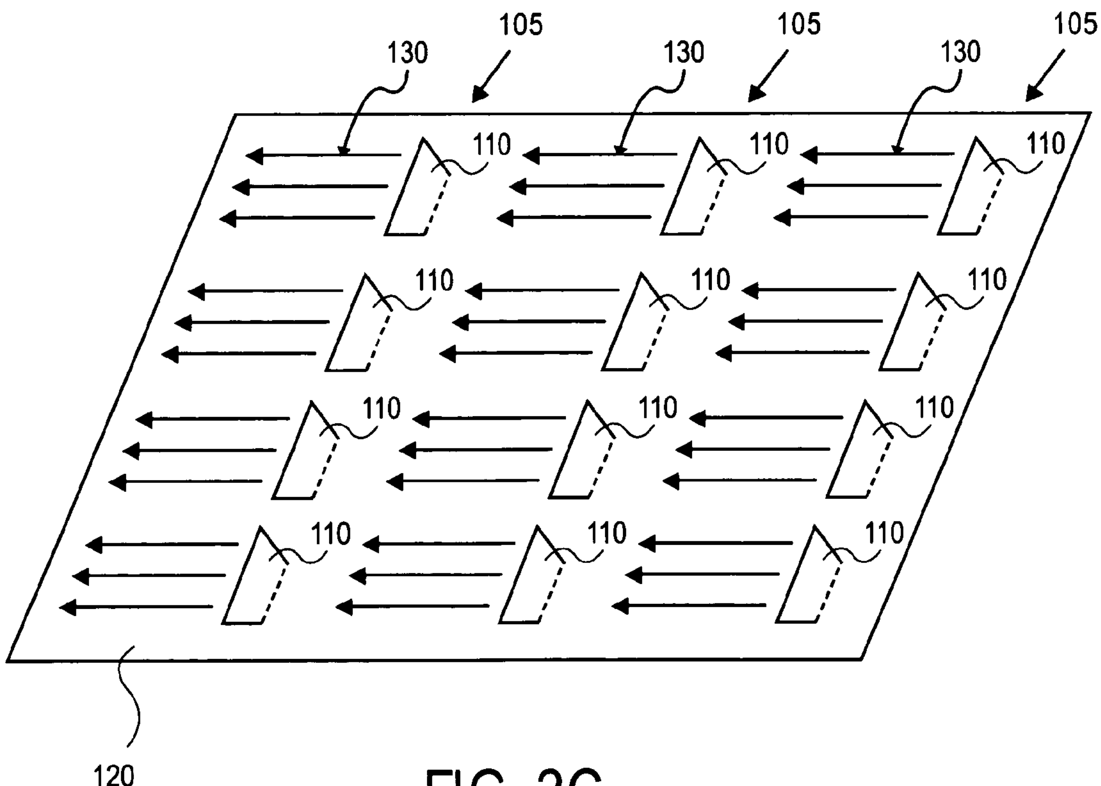

105
105
105
130
130
130
110
110
110
110
110
110
110
110
110
110
110
110
120

FIG. 2C

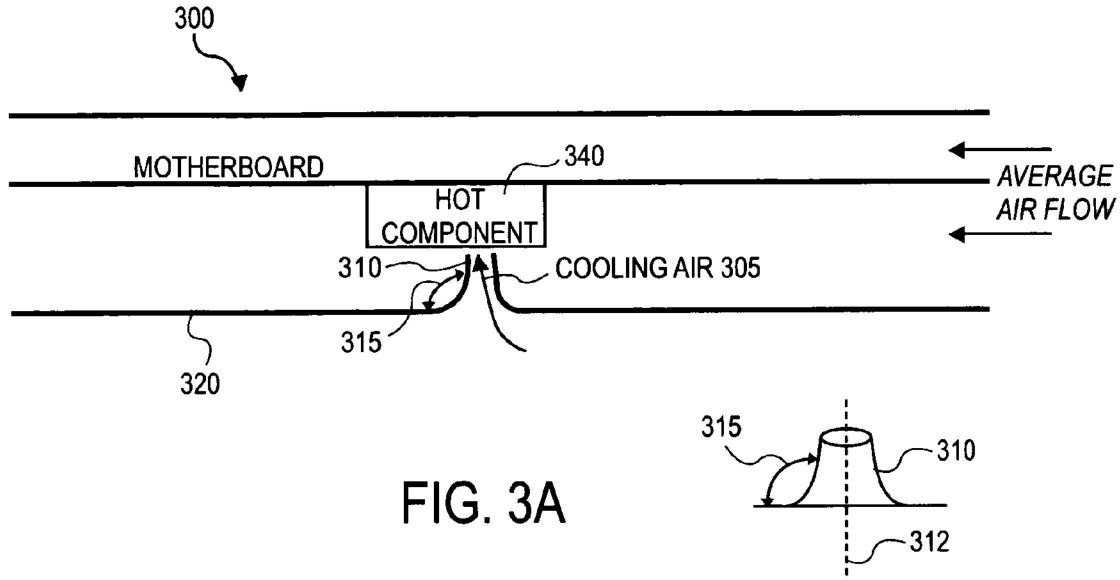
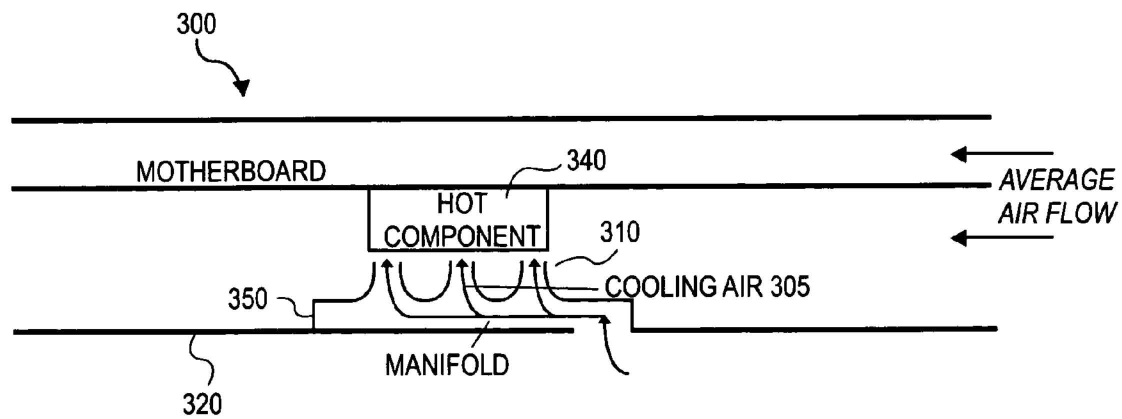

300
MOTHERBOARD
340
HOT
COMPONENT
AVERAGE
AIR FLOW
310
COOLING AIR 305
315
320
315
310
312

FIG. 3A


300
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340
HOT
COMPONENT
AVERAGE
AIR FLOW
310
COOLING AIR 305
350
MANIFOLD
320

FIG. 3B

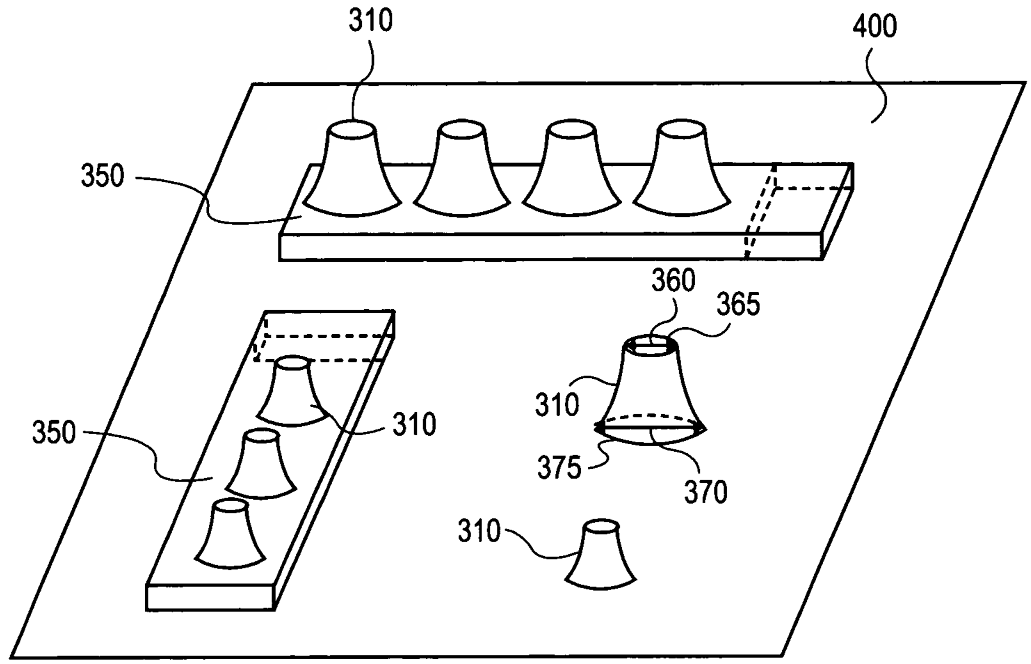


FIG. 4A

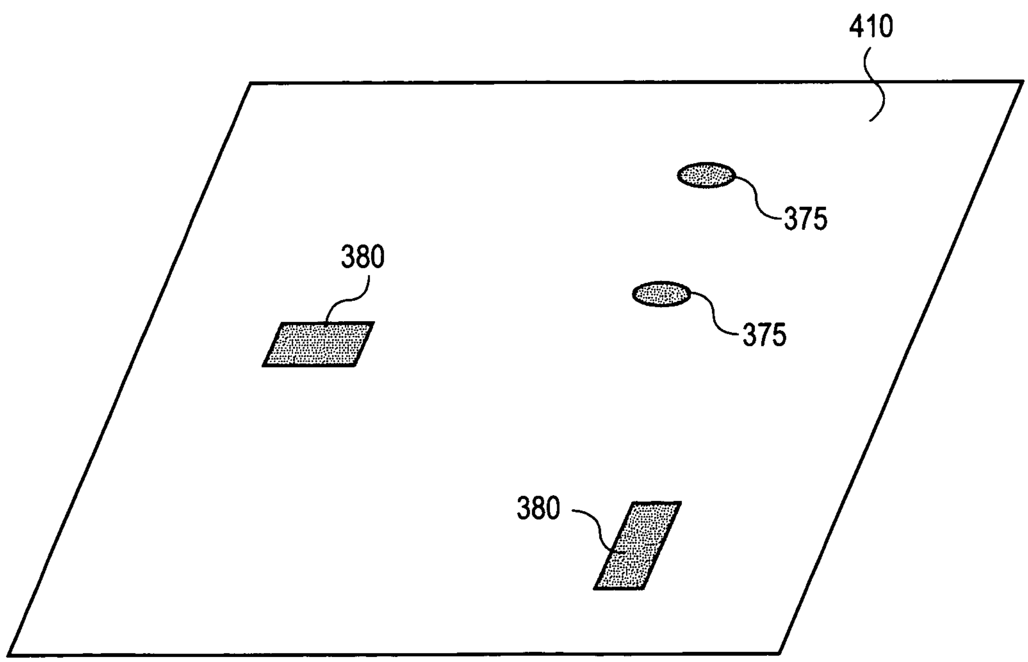
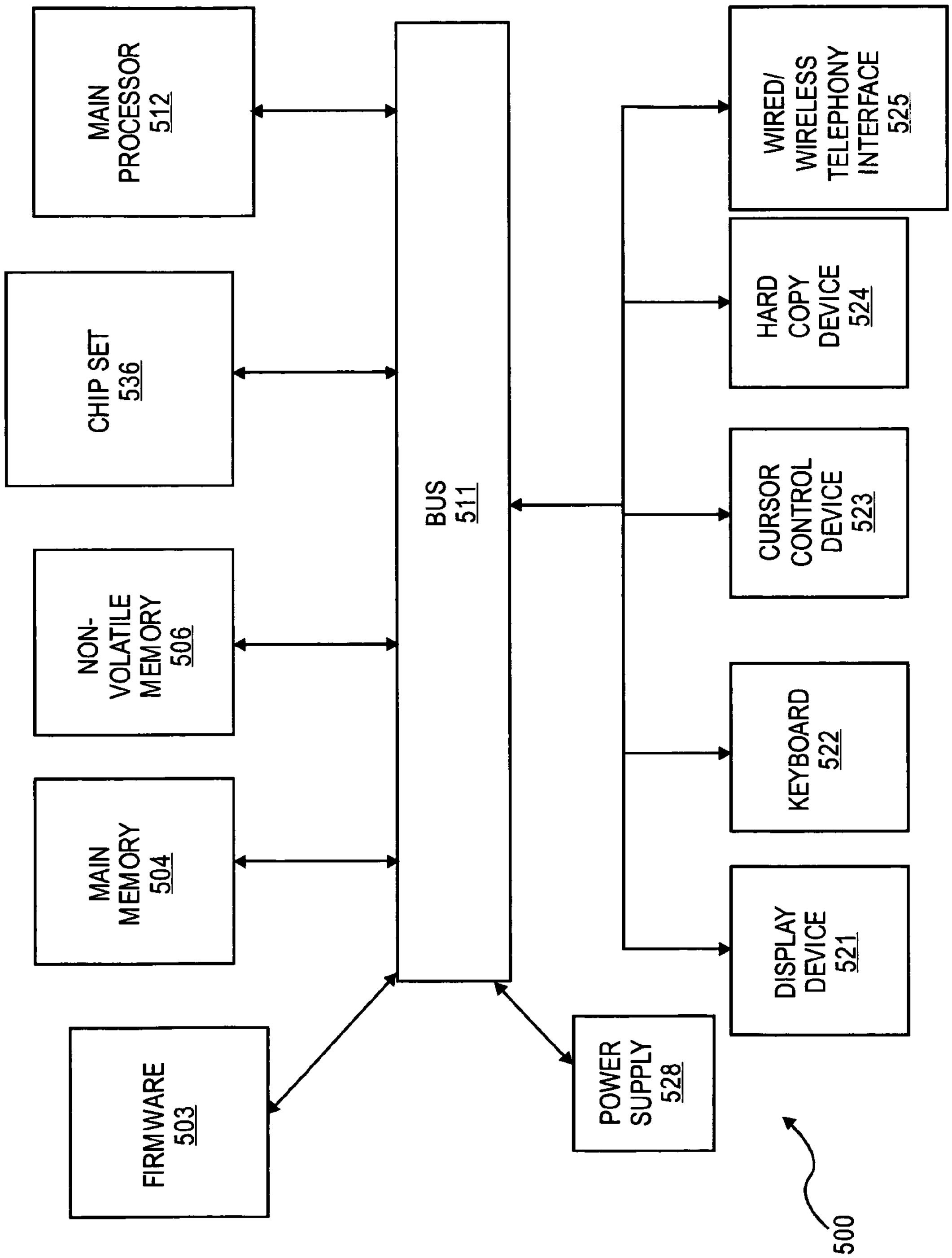


FIG. 4B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CHIP SET 536
NON-VOLATILE MEMORY 506
MAIN MEMORY 504
FIRMWARE 503
BUS 511
POWER SUPPLY 528
WIRED/ WIRELESS TELEPHONY INTERFACE 525
HARD COPY DEVICE 524
CURSOR CONTROL DEVICE 523
KEYBOARD 522
DISPLAY DEVICE 521
500

FIG. 5

APPARATUS AND METHOD TO EFFICIENTLY COOL A COMPUTING DEVICE

BACKGROUND

1. Field

The present invention relates to the field of heat management of computing devices, and in particular the cooling of heat generating components and exterior walls of mobile computing devices.

2. Discussion of Related Art

Heat management can be critical in many applications. Excessive heat can cause damage to or degrade the performance of mechanical, chemical, electric, and other types of devices. Heat management becomes more critical as technology advances and newer devices continue to become smaller and more complex, and as a result run at higher power levels and/or power densities.

Modern electronic circuits, because of their high density and small size, often generate a substantial amount of heat. Complex integrated circuits (ICs), especially microprocessors, generate so much heat that they are often unable to operate without some sort of cooling system. Further, even if an IC is able to operate, excess heat can degrade an IC's performance and can adversely affect its reliability over time. Inadequate cooling can cause problems in central processing units (CPUs) used in personal computers (PCs), which can result in system crashes, lockups, surprise reboots, and other errors. The risk of such problems can become especially acute in the tight confines found inside mobile computers and other portable computing and electronic devices.

As the processing powers of mobile computing devices continue to increase, the temperatures of the outer walls of the mobile computing devices will continue to rise to unacceptable levels. The temperatures are becoming the highest within the regions of the memory, central processing unit (CPU), chipset and voltage regulator (VR). To overcome the increase of heat in these locations, vents have been placed in strategic locations to reduce the temperatures.

Prior methods for dealing with such cooling problems have included using simple vent systems in the outer walls of a mobile device. But, as the amount of cooling air available within mobile computing devices is reduced as the mobile devices are scaled down, the vent system becomes less and less efficient.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is an illustration of an embodiment of a cross-sectional view of a louvered vent within a mobile computing device.

FIGS. **1**B-**1**D illustrate cross-sectional views of different embodiments of the shape of the louvered vent.

FIG. **2**A is an illustration of an overhead view of an embodiment of the inside surface of a wall having a row of louvered vents.

FIG. **2**B is an illustration of an overhead view of an embodiment of the outside surface of a wall having a row of louvered vents.

FIG. **2**C is an illustration of an overhead view of an embodiment of the outside surface of a wall having a series of rows of louvered vents.

FIG. **3**A is an illustration of a cross-sectional view of an embodiment of a nozzle vent within a mobile computing device.

FIG. **3**B is an illustration of a cross-sectional view of an embodiment of a manifold of nozzle vents.

FIG. **4**A illustrates an embodiment of an inside view of a wall having nozzle vents.

FIG. **4**B is an illustration of an embodiment of an outside view of a wall having nozzle vents.

FIG. **5** is an illustration of an embodiment of a mobile computing device system that may employ embodiments of louvered vents or nozzle vents to cool the mobile computing device system.

DETAILED DESCRIPTION

Described herein are methods and devices to decrease the temperatures of the walls of mobile computing devices and of the components within the mobile computing devices. In the following description numerous specific details are set forth. One of ordinary skill in the art, however, will appreciate that these specific details are not necessary to practice embodiments of the invention. While certain exemplary embodiments of the invention are described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative and not restrictive of the current invention, and that this invention is not restricted to the specific constructions and arrangements shown and described because modifications may occur to those ordinarily skilled in the art. In other instances, well known semiconductor fabrication processes, techniques, materials, equipment, etc., have not been set forth in particular detail in order to not unnecessarily obscure embodiments of the present invention.

Embodiments disclosed herein include devices to cool the walls of a mobile computing device and to cool the heat generating components of the mobile computing device. In one embodiment, a louvered vent is formed within an external wall of a mobile computing device to create an air curtain between the external wall and a heat generating component to cool the external wall. In another embodiment, a nozzle vent is formed within the external wall of a mobile computing device to flow cooling air at a heat generating component to cool the heat generating component.

FIG. **1**A illustrates an embodiment of a louvered vent **110** that has been formed within the external wall **120** of a mobile computing device **100** to form an air curtain **130** between the external wall **120** and a heat generating component **140** to cool the external wall. An air curtain **130** is a thin film of air that is formed along the inside of the external wall **120**. The air curtain **130** is formed inside the mobile computing device **100** to supplement the average airflow **150** available on the inside of the mobile computing device **100**. The air curtain **130** is formed by the fluid dynamics of the louvered vent **110**. The purpose of the air curtain **130** is to isolate the external wall **120** from the heat generating components **140**. The shape of the louvered vent **110** is designed to redirect the flow of the air coming into the mobile computing device **100** from outside of the external wall **120**. The louvered vent **110** illustrated in FIG. **1**A is a curved louvered vent **110**. FIGS. **1**B, **1**C and **1**D illustrate alternative embodiments of the shape of the louvered vent **110**.

In FIG. **1**B an angled louvered vent **110** is illustrated. The angled louvered vent **110** of FIG. **1**B may have any angle with respect to the external wall **120** that is sufficient to form a curtain of cooling air **130**, but more particularly may have an angle with respect to the external wall **120** in the approximate range of 15 degrees and 45 degrees.

FIG. **1**C illustrates a squared of chamber louvered vent **110**. The height **102** of the squared off chamber may vary depending on the dimensions of the interior of the mobile computing device **100**, but in one particular embodiment where the mobile computing device **100** is a laptop computer, the height **102** of the squared off chamber may be in the approximate range of 1 millimeters (mm)-3 mm. The length **104** of the squared off chamber louvered vent **110** may be any length sufficient to form the air curtain **130** along the external wall **120**.

FIG. **1**D illustrates a hooded louvered vent **110**. The hooded louvered vent **110** may be curved, angled, or squared and forms an enclosed louvered vent **110** to more specifically focus the air curtain **130**. The hooded louvered vent **110** may have a width and a height sufficient to create an air curtain **130** that is capable of reducing the temperature of the external wall **120**.

FIGS. **2**A and **2**B illustrate an embodiment of angled louvered vents **110** formed in a row **105** in an external wall **120** of a mobile computing device **100**. FIG. **2**A illustrates a top view of the inside surface of the external wall **120**. The row **105** of louvered vents **110** is seen in this figure. A row **105** of louvered vents **110** may be used to form many air curtains **130** along the inside surface of the external wall **120**. The multiple air curtains **130** may in effect form a continuous air curtain **130**. FIG. **2**B illustrates a bottom view of the outside surface of the external wall **120** to illustrate the openings **160** of the louvered vents **110**. In an alternate embodiment, not shown, a louvered vent **110** may be formed that crosses a substantial width or length of the external wall **120**. Many variations of length, width, and positioning of the louvered vents **110** may be used depending on the placement of the heat generating components **140** within the mobile computing device and depending on how many air curtains are sufficient to cool the external wall **120**.

FIG. **2**C illustrates an embodiment where a series of rows **105** of louvered vents **110** are positioned to create an air curtain formed of the combined series of air curtains **130** over substantially the entire external wall **120**. The rows **105** of the louvered vents may be positioned approximately 10 mm-30 mm apart. The distance between the rows **105** of louvered vents **110** is determined by the distance at which the air curtain begins to break up so that the next row **105** of louvered vents **110** can take over to form an air curtain over the external wall **120** to cool the external wall **120**.

In an embodiment, the positioning of the louvered vents **110** may be determined by the placement of the heat generating components within the mobile computing device **100**. In this embodiment, the louvered vents **110** may be positioned to one side of the heat generating components **140** so that an air curtain **130** is formed substantially beneath the heat generating components **140** as illustrated in FIG. 1A. The louvered vents **110** described in these embodiments may decrease the temperature of the external wall **120** by approximately 20%-25% or more. The amount by which the temperature of the external wall **120** is decreased may vary depending on the type of louvered vent **110**, the number of louvered vents **110**, and the positioning of the louvered vents **110**.

The louvered vents **110** may be formed within the external wall **120** by machining, stamping, or molding, for example. The louvered vents **110** may be formed of any material such as plastic polymers or metal. In one embodiment, the louvered vents **110** are formed of metal and have a length sufficient to provide electromagnetic interference (EMI) shielding.

FIG. **3**A illustrates an embodiment of a mobile computing device **300** having a nozzle vent **310**. The mobile computing device **300** has a heat generating component **340** and an external wall **320** near the heat generating component **340**. The nozzle vent **310** is formed within the external wall **320** to flow cooling air at the heat generating component **340**. By directing the flow of the cooling air **305** through the nozzle vent **310**, significant heat transfer rates between the cooling air **305** and the heat generating component **340** can be achieved. Additionally, the use of the available cooling air is maximized. In one embodiment, the center vertical axis **312** of the nozzle vent **310** of FIG. **3**A may be at a 90 degree angle with respect to the external wall **320** and pointed directly at the heat generating component **340**. In an alternate embodiment, the center vertical axis **312** of the nozzle vent **310** may be angled with respect to the external wall **320**. The angle **315** that is formed between the external wall **320** and the center vertical axis **312** of the nozzle jet may be between approximately 30 degrees and 90 degrees, and more particularly approximately 45 degrees. The nozzle vent **310** may be angled to direct the cooling air **305** at the heat generating component **340** to bring the cooling air **305** into contact with as much surface area of the heat generating component **340** as possible.

FIG. **3**B illustrates an embodiment of a mobile computing device **300** where a manifold **350** of nozzle vents **310** is used to distribute the cooling air **305** to specific locations of a heat generating component **340**. The manifold **350** may also be used to direct cooling air **305** to more than one heat generating component **340**. The nozzle vents **310** that are part of the manifold **350** may also be arranged at various angles relative to the external wall **320** to direct the cooling air **305** to strategic locations to maximize the cooling of the heat generating components **340**.

FIGS. **4**A and **4**B illustrate an embodiment of an external wall **320** of a mobile computing device **300**. The external wall **320** of the FIGS. **4**A and **4**B has two manifolds **350** of nozzle vents **310** and two individual nozzle vents **310**. These figures illustrate a portion of an embodiment of an external wall and are not meant to be limiting in any way. FIG. **4**A illustrates the inside surface **400** of an external wall **320**. The inside surface of the external wall **320** may have any arrangement of individual nozzles **310** and nozzle manifolds **350** possible, depending on the layout of the heat generating components **340** within the mobile computing device **300**.

FIG. **4**A illustrates one example of an outside surface **410** of the external wall **320** having one possible layout of nozzle vents **310**. In one embodiment each of the nozzle vents **310** within the mobile computing device may have the same dimensions. In another embodiment, the dimensions of the nozzle vents **310** within the mobile computing device **300** may vary depending on the size of the heat generating components **340**. The diameter **360** of the openings **365** and the diameter of the base **370** of the nozzle vents **310** may vary depending on the amount of cooling air **305** needed to cool down the heat generating components to a temperature sufficient to prevent the excessive heating of the external wall **320** of the mobile computing device. The diameter **360** of the openings **365** of the nozzle vents **310** and the diameter of the base **370** of the nozzle vents **310** may be varied depending on the size of the heat generating components **340** and the amount of cooling air **305** needed. In one embodiment, the diameter of the openings **365** of the nozzle vents may be in the approximate range of 2 millimeters (mm) and 5 mm and the diameter of the base **370** of the nozzle vents may be in the approximate range of 5 mm and 10 mm.

Alternatively a manifold **350** of nozzle vents **310** may be used to provide the necessary amount of cooling air **305**. FIG. **4**A illustrates two examples of a manifold **350** of nozzle vents **310**. The manifolds **350** may have any number of nozzle vents

310 depending on the size and/or number of heat generating components 340 within the mobile computing device. The dimensions of the nozzle vents 310 that are part of a manifold 350 may be similar or different than the dimensions of the individual nozzle vents 310 on the inside surface of the external wall 320 of a mobile computing device 300. FIG. 4B illustrates the outside of the external wall 320, illustrating the base openings 375 of the nozzle vents 310 and the manifold openings 380. In an alternate embodiment, the external wall 320 may further include one or more louvered vents 110 to form an air curtain between the external wall 320 and the heat generating components 340 to create a buffer of cooler air between the external wall 320 and the heat generating component 340.

FIG. 5 illustrates a block diagram of an example computer system that may use an embodiment of the louvered vents 110 or nozzle vents 310 to cool the external walls or heat generating components of a mobile computing device. In one embodiment, computer system 500 comprises a communication mechanism or bus 511 for communicating information, and an integrated circuit component such as a processor 512 coupled with bus 511 for processing information. One or more of the heat generating components or devices in the computer system 500 such as the processor 512 or a chip set 536 may be cooled by an embodiment of the nozzle vents 310 in combination with the louvered vents 110 to cool the external walls of the mobile computing device.

Computer system 500 further comprises a random access memory (RAM) or other dynamic storage device 504 (referred to as main memory) coupled to bus 511 for storing information and instructions to be executed by processor 512. Main memory 504 also may be used for storing temporary variables or other intermediate information during execution of instructions by processor 512.

Firmware 503 may be a combination of software and hardware, such as Electronically Programmable Read-Only Memory (EPROM) that has the operations for the routine recorded on the EPROM. The firmware 503 may embed foundation code, basic input/output system code (BIOS), or other similar code. The firmware 503 may make it possible for the computer system 400 to boot itself.

Computer system 500 also comprises a read-only memory (ROM) and/or other static storage device 506 coupled to bus 511 for storing static information and instructions for processor 512. The static storage device 506 may store OS level and application level software.

Computer system 500 may further be coupled to a display device 521, such as a cathode ray tube (CRT) or liquid crystal display (LCD), coupled to bus 511 for displaying information to a computer user. A chipset, such as chipset 536, may interface with the display device 521

An alphanumeric input device (keyboard) 522, including alphanumeric and other keys, may also be coupled to bus 511 for communicating information and command selections to processor 512. An additional user input device is cursor control device 523, such as a mouse, trackball, trackpad, stylus, or cursor direction keys, coupled to bus 511 for communicating direction information and command selections to processor 512, and for controlling cursor movement on a display device 512. A chipset, such as chipset 536, may interface with the input output devices.

Another device that may be coupled to bus 511 is a hard copy device 524, which may be used for printing instructions, data, or other information on a medium such as paper, film, or similar types of media. Furthermore, a sound recording and playback device, such as a speaker and/or microphone (not shown) may optionally be coupled to bus 511 for audio interfacing with computer system 500. Another device that may be coupled to bus 511 is a wired/wireless communication capability 525.

Computer system 500 has a power supply 528 such as a battery, AC power plug connection and rectifier, etc.

Several embodiments of the invention have thus been described. However, those of ordinary skill in the art will recognize that the invention is not limited to the embodiments described, but can be practiced with modification and alteration within the scope and spirit of the appended claims that follow.

We claim:

1. A mobile computing device, comprising:
- a component capable of generating heat;
- an external wall; and
- a fixed louvered vent formed within the external wall to create an air curtain using fluid dynamic characteristics of the fixed louvered vent, the air curtain comprising a film of air formed along and in direct contact with an inside surface of and substantially parallel to the external wall including the fixed louvered vent, the air curtain formed between and in direct contact with both the external wall and the heat generating component, wherein the louvered vent is positioned to one side of the heat generating component and is configured to create the air curtain having an area substantially similar to an area of heat created by the heat generating component, the air curtain to supplement an average airflow inside the mobile computing device and to deflect at least a portion of the heat from the heat generating component from reaching the external wall.

2. The apparatus of claim 1, wherein the heat generating component is a central processing unit.

3. The apparatus of claim 1, wherein a shape of the louvered vent is designed to draw air from outside of the external wall into the mobile computing device to form the air curtain.

4. The apparatus of claim 1, wherein the louvered vent extends from the inside surface of the external wall into the mobile computing device.

5. The apparatus of claim 1, wherein the louvered vent is formed of a metal to provide electromagnetic interference protection.

6. The apparatus of claim 1, wherein the louvered vent is shaped as a squared off chamber.

7. The apparatus of claim 1, wherein the louvered vent has a curved shape.

8. The apparatus of claim 1, wherein the louvered vent is formed at an angle, the angle being in an approximate range between 30 degrees and 60 degrees with respect to the external wall.

9. The apparatus of claim 1, wherein the louvered vent is part of a row of louvered vents positioned to create the air curtain along the external wall.

10. A method, comprising:
- generating heat within a mobile computing device with a heat generating component;
- drawing air from outside the mobile computing device through a fixed louvered vent formed within an external wall of the mobile computing device using fluid dynamic characteristics of the fixed louvered vent, the fixed louvered vent positioned to one side of and in direct contact with the heat generating component and configured to create an air curtain comprising a film of air formed along and in direct contact with an inside surface of and substantially parallel to the external wall including the fixed louvered vent, the air curtain having an area substantially similar to an area of heat created by

the heat generating component, the air curtain configured to supplement an average airflow inside the mobile computing device and to deflect at least a portion of the heat from the heat generating component from reaching the external wall; and

cooling the external wall opposite the heat generating component using the air curtain with the air drawn from outside the mobile computing device.

11. The method of claim **10**, further comprising forming a substantially continuous air curtain along the external wall of the mobile computing device.

12. A computing device, comprising:

a heat generating component;

a housing containing the heat generating component, the housing having an external wall having a fixed louvered vent formed therein and positioned to one side of and in direct contact with the heat generating component and configured to form an air curtain comprising a film of air formed along and in direct contact with an inside surface of and substantially parallel to the external wall including the fixed louvered vent using fluid dynamic characteristics of the fixed louvered vent, the air curtain having an area substantially similar to an area of heat created by the heat generating component, the air curtain formed between the external wall and the heat generating component to supplement an average airflow inside the housing; and

a battery to power the computing device.

13. The computing device of claim **12**, wherein the housing has more than one louvered vent formed in the external wall.

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